EVENT ABSTRACT

20 Years of NEST: A Mature Brain Simulator

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Efficient and reliable simulation tools are essential for progress in brain research. Since the early days of neuronal computing (Farley & Clark, 1954), a wide range of simulators have been developed, each specialized on one or few spatial and temporal scales (Brette et al., 2007). But the reliable and reproducible simulation of such complex systems as the brain is a very demanding challenge. Thus, the Computational Neuroscience community concentrated on a few reliable and widely used simulation tools in recent years. Neuronal network simulation is thus coming of age: Just as our colleagues in electrophysiology, we begin to base our work increasingly on the use of standard tools, with modifications and adaptations for our particular research, instead of building home-brew solutions from scratch. This concentration was not least the result of a series of large-scale EU funded projects, such as FACETS, BrainScaleS and the recently announced Human Brain Project.

From its humble beginnings as a PhD-student project 20 years ago, the Neural Simulation Tool NEST (Gewaltig & Diesmann, 2007) saw its first incarnation as the SYNOD simulator in 1995 (Diesmann et al., 1995), leading to exciting results on synfire chains early on (Diesmann et al., 1999). By tightly coupling software development with computational neuroscience research (Kunkel et al., 2010), simulator technology evolved steadily, facilitating new scientific insight at (nearly) every step. Some key examples were parallelization (Morrison et al., 2005; Plesser et al., 2007), exact integration of model equations (Rotter & Diesmann, 1999), precise spike times in a time-driven simulator (Morrison et al., 2007; Hanuschkin et al., 2010), spike- time-dependent (Morrison et al., 2007) and neuro-modulated plasticity (Potjans et al., 2010), and a Topology module for spatially structured networks (Plesser & Enger, 2013). Streamlined data-structures (Kunkel et al., 2011) allow NEST to efficiently exploit the capabilities of some of the largest computers on Earth for simula- tions on the brain scale (Helias et al., 2012). Systematic quality assurance through testsuites (Eppler et al., 2009) and continuous integration technology (Zaytsev & Morrison, 2013) ensure simulator reliability (within limits). With a user-friendly Python-based interface (Eppler et al., 2008; Gewaltig et al., 2012), integration with PyNN (Davison et al., 2008) for simulator-independent scripting and MUSIC support (Djurfeldt et al., 2010) for integrated multi-scale simulation, NEST is a powerful simulation tool for brain-scale simulations today.

NEST has been publicly available since 2004 and has been taught at summer schools and graduate courses since, training a generation of computational scientists. This has lead to a steady increase in computational neuroscience publications based on NEST simulations in recent years (see http://www.nest-initiative.org for a list), indicating that NEST is indeed establishing itself as a widely used tool for the simulation of large networks of (comparatively) simple model neurons.

As of the NEST 2.0 release in 2012, NEST is available under the GNU Public License to ensure wide dissemination. The further development of NEST is chaperoned by the NEST Initiative, a non-for-profit organization incorporated in Ecublens, Switzerland, which is open for interested scientists. We are currently preparing to move NEST source code to a distributed version control system, allowing all NEST users ”real time” access to bug fixes and improvements, and to facilitate contributions by the NEST Community.

In our demonstration, we will illustrate the capabilities and versatility of NEST. We will in particular focus on three complementary approaches to simulating large-scale cortical networks: A data-driven approach based on detailed connectivity information (based on data from the Blue Brain Project), constructive network generation, based on connectivity patterns (Potjans &

Diesmann, 2012), and simulation of advanced 3D topological networks.

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Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

References

Brette, R., Rudolph, M., Carnevale, T., Hines, M., Beeman, D., Bower, J. M., Diesmann, M., Morrison, A., Goodman, P. H., Jr., F. C. H., Zirpe, M., Natschläger, T., Pecevski, D., Ermentrout, B., Djurfeldt, M., Lansner, A., Rochel, O., Vieville, T., Muller, E., Davison, A. P., Boustani, S. E., & Destexhe, A. (2007). Simulation of networks of spiking neurons: A review of tools and strategies. J Comput Neurosci 23, 349–398.
Davison, A., Brüderle, D., Eppler, J., Kremkow, J., Muller, E., Pecevski, D., Perrinet, L., & Yger, P. (2008). PyNN: a common interface for neuronal network simulators. Front Neuroinform 2, 11.
Diesmann, M., Gewaltig, M.-O., & Aertsen, A. (1995). SYNOD: an environment for neural sytems simula- tions. language interface and tutorial. Technical Report GC-AA-/95-3, The Weizmann Instiute of Science, The Grodetsky Center for Research of Higher Brain Functions, Weizmann Institute of Science, Israel.
Diesmann, M., Gewaltig, M.-O., & Aertsen, A. (1999). Conditions for stable propagation of synchronous spiking in cortical neural networks. Nature 402, 529–533.
Djurfeldt, M., Hjorth, J., Eppler, J. M., Dudani, N., Helias, M., Potjans, T. C., Bhalla, U. S., Diesmann, M., Kotaleski, J. H., & Ekeberg, O. (2010). Run-time interoperability between neuronal network simulators based on the music framework. Neuroinformatics 8(1), 43–60.
Eppler, J. M., Helias, M., Muller, E., Diesmann, M., & Gewaltig, M.-O. (2008). PyNEST: A convenient interface to the NEST simulator. Front Neuroinformatics 2, 12.
Eppler, J. M., Kupper, R., Plesser, H. E., & Diesmann, M. (2009). A testsuite for a neural simulation engine. In Frontiers in Neuroinformatics. Conference Abstract: 2nd INCF Congress of Neuroinformatics, Plzen. International Neuroinformatics Coordinating Facility.
Farley, B. G., & Clark, W. A. (1954). Simulation of self-organized systems by digital computer. IEEE Trans Info Theory IT-4, 76–84.
Gewaltig, M.-O., & Diesmann, M. (2007). Nest (neural simulation tool). Scholarpedia 2(4), 1430.
Gewaltig, M.-O., Morrison, A., & Plesser, H. E. (2012). NEST by example: An introduction to the neural simulation tool NEST. In N. Le Novère (Ed.), Computational Systems Neurobiology, Chapter 18, pp. 533–558. Dordrecht: Springer Science+Business Media.
Hanuschkin, A., Kunkel, S., Helias, M., Morrison, A., & Diesmann, M. (2010). A general and efficient method for incorporating exact spike times in globally time-driven simulations. Front Neuroinformatics 4, 113.
Helias, M., Kunkel, S., Masumoto, G., Igarashi, J., Eppler, J. M., Ishii, S., Fukai, T., Morrison, A., & Diesmann, M. (2012). Supercomputers ready for use as discovery machines for neuroscience. Front Neuroinform 6, 26.
Kunkel, S., Eppler, J. M., Plesser, H. E., Gewaltig, M.-O., Diesmann, M., & Morrison, A. (2010). NEST: Science-driven development of neuronal network simulation software. In Frontiers in Neuroscience. Conference Abstract: Neuroinformatics 2010.
Kunkel, S., Potjans, T. C., Eppler, J. M., Plesser, H. E., Morrison, A., & Diesmann, M. (2011). Meeting the memory challenges of brain-scale network simulation. Front. Neuroinform. 5, 35.
Morrison, A., Aertsen, A., & Diesmann, M. (2007). Spike-time dependent plasticity in balanced

recurrent networks. Neural Comput 19, 1437–1467.
Morrison, A., Mehring, C., Geisel, T., Aertsen, A., & Diesmann, M. (2005). Advancing the boundaries of high connectivity network simulation with distributed computing. Neural Comput 17, 1776–1801.
Morrison, A., Straube, S., Plesser, H. E., & Diesmann, M. (2007). Exact subthreshold integration with continuous spike times in discrete time neural network simulations. Neural Comput 19, 47–79.
Plesser, H. E., & Enger, H. (2013). Nest topology user manual.
Plesser, H. E., Eppler, J. M., Morrison, A., Diesmann, M., & Gewaltig, M.-O. (2007). Efficient parallel simulation of large-scale neuronal networks on clusters of multiprocessor computers. In A.-M. Kermarrec, L. Bougé, & T. Priol (Eds.), Euro-Par 2007: Parallel Processing, Volume 4641 of Lecture Notes in Computer Science, Berlin, pp. 672–681. Springer-Verlag.
Potjans, T. C., & Diesmann, M. (2012). The cell-type specific cortical microcircuit: Relating structure and activity in a full-scale spiking network model. Cereb Cortex.
Potjans, W., Morrison, A., & Diesmann, M. (2010). Enabling functional neural circuit simulations with distributed computing of neuromodulated plasticity. Front Comput Neurosci 4, 141.
Rotter, S., & Diesmann, M. (1999). Exact digital simulation of time-invariant linear systems with applications to neuronal modeling. Biol Cybern 81, 381–402.
Zaytsev, Y. V., & Morrison, A. (2013). Increasing quality and managing complexity in neuroinformatics software development with continuous integration. Front Neuroinform 6, 31.

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